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BENDING CAPACITY OF COLD-FORMED LIPPED C-CHANNEL WITH INTERMEDIATE STIFFENERS

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ABSTRACT

This paper describes a four point bending test to determine the bending capacity of cold-formed steel (CFS) beams with intermediate stiffeners. As established by researches all around the world, the load-carrying capacity and the buckling behaviour of compression components of CFS sections can improve considerably with the addition of intermediate stiffeners. However, when the dimensions of the actual intermediate stiffener do not fulfil the required minimum moment of inertia recommended in the design standard, the load-carrying capacity of the member has to be determined either on the basis of a flat element disregarding the intermediate stiffener or through tests. In this study, grade G550 lipped C-channels with intermediate web stiffeners were tested to determine the additional capacity provided by the stiffeners as compared to lipped C-channels without intermediate web stiffeners. The sections were tested in the major bending axis where the stiffened web element experienced a stress gradient. The experimental ultimate moment (M_T) obtained was compared with the theoretical elastic bending moment (M_e) and the design capacity according to Australian/New Zealand Standard ($M_{AS/NZS}$).

KEYWORDS: Cold-Formed Steel, Lightweight, C-Channel, Bending Capacity, Stiffeners

INTRODUCTION

Cold-formed steel (CFS) sections are commonly used in a wide range of applications. In Malaysia, these sections have been extensively used in lightweight roof constructions. These structural members are easily formed using thin metal sheet through rolled forming or press braking methods. The products of these are sections of high strength to weight ratio. These sections however, are light gauge and as a result are susceptible to buckling. Nevertheless, it was established worldwide that the load-carrying capacity and the buckling behavior of compression elements of light gauge sections can be significantly improved with the addition of stiffeners [1, 2, 3, 4].s

In order to stay competitive, manufacturers have produced different section shapes utilizing intermediate stiffeners. However, if the dimensions of the intermediate stiffener do not fulfill the minimum requirement recommended in the design standard, the load-carrying capacity of the section has to be determined either on the basis of a flat element disregarding the intermediate stiffener or through tests [4].

In this study, grade G550 lipped C-channels with intermediate web stiffeners were tested. The sections had a nominal yield stress of 550 MPa. The nominal dimensions of the sections are, web depth = 75 mm, flange width1 = 38 mm, flange width2 = 40mm and lip length = 14 mm as shown in Figure 1. The reason for the flanges to have unequal lengths was to facilitate the coupling of the sections. In this particular section, the moment of inertia, I_s of the intermediate

stiffeners did not meet the minimum requirement stated in the design standard. And for simplicity, the design capacity of the section was estimated on the basis of flat element of a plain lipped C-channel without intermediate stiffeners. It was the aim of this study to determine the actual bending capacity of these C channels and to calculate the increase in strength due to the addition of the intermediate stiffeners. Only the capacity of the sections in the major axis was considered.

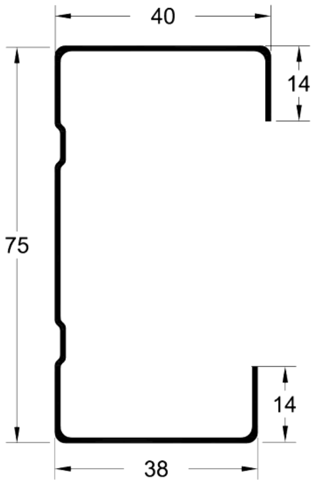

Figure 1: Lipped C-Channel with Intermediate Web Stiffeners (Dimensions in mm)

EXPERIMENTAL INVESTIGATIONS

Test Specimens

The specimens used in this study were cold-formed lipped C-channels. The channels were available in three different thicknesses; 0.8 mm, 1.0 mm and 1.2 mm. They were labeled as C07508, C07510 and C07512 respectively where the first letter C refers to C-channel, the following three digits 075 represents the depth of the section and the last two digits denotes the thickness of the section. The dimensions of the specimens are as shown in Table 1.

Table 1: Dimensions of Specimens

Specimen	Depth (mm)	Width1 (mm)	Width2 (mm)	Thickness (mm)
C07508	75	38	40	0.8
C07510	75	38	40	1.0
C07512	75	38	40	1.2

All the test specimens were fabricated from high strength aluminium zinc coated, grade G550 AZ150 steel metal sheets. The yield strength for each specimen was determined using tensile coupon test in accordance to the Australian standard, AS1391 [5]. Figure 2 shows the dimension of the coupons used. The coupons were tested using a T-machine. Load was applied slowly at a rate of 0.5mm/s. The mechanical properties obtained from the tensile coupon tests are as shown in Table 2.

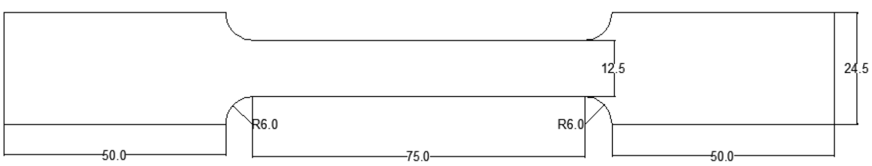

Figure 2: Dimensions of Tensile Coupon (Dimensions in mm)

Table 2: Mechanical Properties of test Specimens from Tensile Coupon Tests

Specimen	$\sigma_{0.2}$ [Mpa]	σ_u [Mpa]	Ɛ [%]
C07508	567	569	2
C07510	583	593	7
C07512	585	587	9

Test Setup

The lipped C-channels were tested using four-point bending test to determine the capacity of the section under pure bending moment. The channel was simply supported at 1.2 m span and loaded with two point loads at a third of its span from the supports. The schematic view of the test setup is as shown in Figure 3.

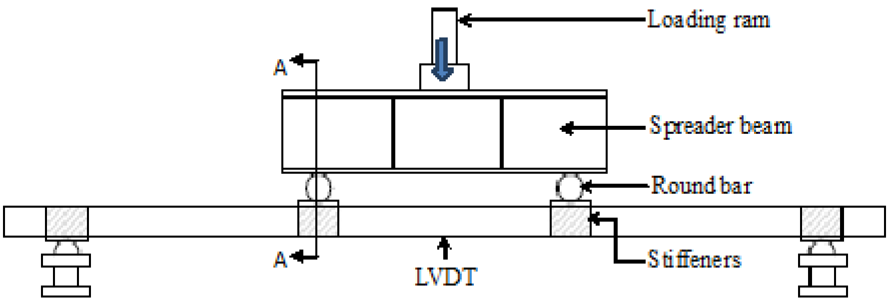

Figure 3: Schematic View of Four Point Bending Test Setup

The channels were tested in the major axis with the stiffened web element experiencing stress gradient. They were arranged back-to-back and stiffened at the supports and loading points using bearing plates and wood blocks. This was to prevent local buckling of the sections under concentrated load. The schematic view of cross section A-A is as shown in Figure 4.

At least 3 samples were tested for each configuration. If the result obtained for any sample fell beyond a 10% limit, the result for that particular sample was omitted and was not included in the analysis. A fourth sample was then tested to replace the inconsistent sample.

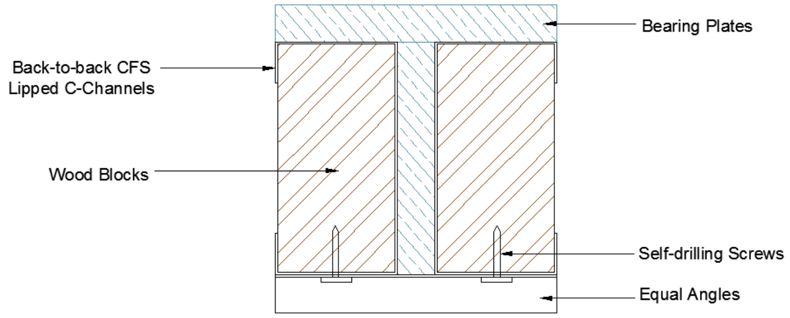

Figure 4: Schematic view of Cross Section A-A

RESULTS AND ANALYSIS

All three sections behaved similarly under load. When load was applied, the section bent until failure occurred. This happened when buckling was observed at the midspan of the section. At this point, displacement continued although there was no increase in the loading.

The results collected from the test were plotted in a force-displacement curve as shown in Figure 5. The ultimate load was taken as the value at the peak of the curve. It was then used to calculate the bending moment capacity of the section by multiplying half of the ultimate static applied load from the actuator with the distance between the support and the loading point of the specimen as in Eq. 1. The free body diagram and the resulting shear force and bending moment diagrams are shown in Figure 6.

$$M_T = 0.2F \qquad (1)$$

Where:

M_T = Bending moment capacity of tested sample (kNm)

F = Actuator force (kN)

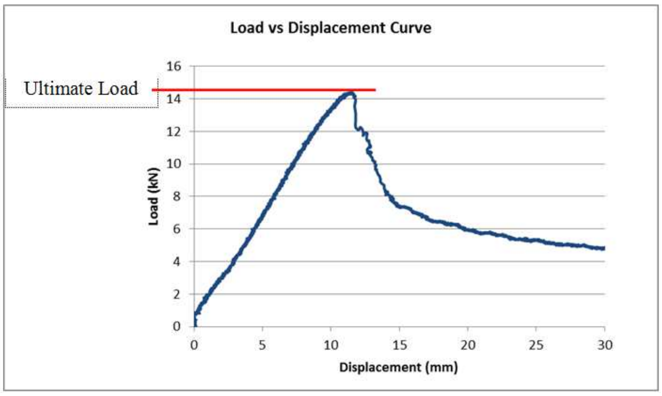

Figure 5: Force Displacement Diagram

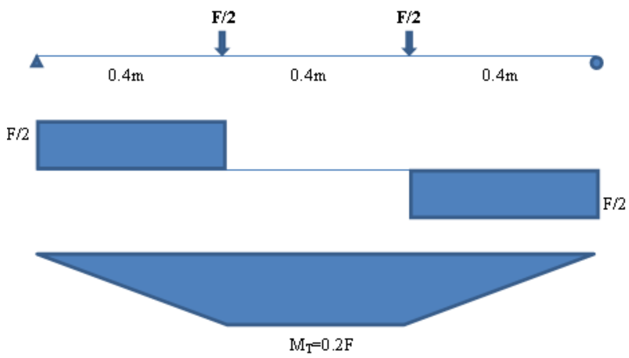

Figure 6: Free Body, Shear Force and Bending Moment Diagrams

COMPARISON OF TEST STRENGTH WITH THEORETICAL AND DESIGN STRENGTHS

The ultimate bending moment capacity of the samples in the same configuration were averaged and tabulated in Table 3. As expected, the bending moment capacity of the sections increased with the thickness of the material used, from 1.40 kNm for section C07508 to 2.30 kNm for section C07510 and 2.90 kNm for section C07512.

The test bending moment was also compared to the theoretical elastic bending moment (M_e) and the design capacity calculated according to Australian/New Zealand standard ($M_{AS/NZS}$) [6]. For both the elastic and design bending moment, the capacity of the sections was calculated based on the nominal cross-section dimensions without intermediate

web stiffeners. The linear method which was commonly known as the midline method was used for computing the properties of the section.

When the test strength was compared with the theoretical elastic capacity, results show that the theoretical elastic capacity was not conservative for the sections tested. All the bending capacity tested for the channels were lower than the theoretical elastic bending capacity calculated except for section C07512 where the ratio of the test to theoretical elastic bending moment (M_T/M_e) had reach unity as shown in Table 3. This indicated that the channel was fully effective when intermediate stiffeners were added to its web element.

However, when the test strength was compared with the unfactored design strength obtained using the Australian/New Zealand Standard, it was demonstrated that the design strength predicted by the Australian/New Zealand Standard was conservative with a maximum difference of 18% in bending strength for the sections tested. For section C07508, the ratio of the test to the unfactored design bending moment ($M_T/M_{AS/NZS}$) was 1.00 as shown in Table 3. This showed that the addition of the intermediate web stiffeners did not improve the capacity of the section. The capacity of the section in bending was identical to the capacity of the section without intermediate stiffeners.

Table 3: Comparison of Test Strength with Theoretical and Design Strengths

Specimen	Test	Theoretical	Design	Comparison	
	M_T (kNm)	Elastic M_e (kNm)	AS/NZS $M_{AS/NZS}$ (kNm)	Elastic $\frac{M_T}{M_e}$	AS/NZS $\frac{M_T}{M_{AS/NZS}}$
C07508	1.40	1.78	1.40	0.79	1.00
C07510	2.30	2.42	2.01	0.95	1.14
C07512	2.90	2.88	2.45	1.00	1.18

CONCLUSIONS

An experimental investigation of cold-formed lipped C-channel with intermediate web stiffeners was presented in this paper. The channels tested were cold-rolled from high strength aluminium zinc coated, grade G550 AZ150 steel sheets of three different thicknesses. The channels were tested using four point bending test in the major axis to determine the bending capacity of the channel under pure bending. Results showed that the bending capacity of the channel increased with the thickness of the material used to form the section. When the test results were compared with the theoretical elastic bending moment, it was shown that the theoretical bending moment was not conservative for the sections tested. Besides that, the test strengths were also compared with the design strengths obtained using the Australian/New Zealand Standard. It was demonstrated that the design strengths predicted by the AS/NZS Standard was conservative for the sections tested. It was also found that the capacity of the C07508 section was not affected when intermediate stiffeners were added to the section.

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